ARS 42-165
February 1970

DESIGN OF A HERBICIDE SPRAYER FOR THE LABORATORY

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

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DESIGN OF A HERBICIDE SPRAYER FOR THE LABORATORY

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SUMMARY

This publication describes a laboratory sprayer for potted plants, and lists materials and construction details. The sprayer was designed for precision application of herbicides to plants grown in greenhouses, nurseries, and growth chambers. It is also useful for studying the distribution of spray from nozzles, for developing spray distribution sampling techniques, and for other studies requiring precision spray applications.

The sprayer consists of a 4- by 16-foot spray booth that accommodates plants up to 4 feet tall. Clear acrylic sheet material encloses the booth. The plant containers rest on an expanded metal tray, and a spray cart that travels the length of the booth on an overhead track delivers the spray. The plant-supporting tray and the spray unit may be raised or lowered independently for various sizes of plants. The spray cart speed is variable from 0 to 5 m.p.h. Spray material is delivered to the nozzle from a small glass jar in a 1-quart pressurized container. Various types and sizes of nozzles, a wide range of spraying pressures, and variable cart speeds may be used for desired rates of application. An activated charcoal filter system removes herbicidal fumes from the air. A control system permits either manual or automatic control of the spray cart and solenoid spray valve.

INTRODUCTION

Precision application of spray materials is important in research involving application of herbicides especially in small-scale studies in the laboratory. Hand-held sprayers are unsatisfactory because of difficulties in obtaining uniform application rates. Hand applications by different people vary greatly.

The danger of contaminating research facilities often prohibits spraying of herbicides in the laboratory. Outdoor treatments are not satisfactory because spray drift may damage nearby vegetation. Weather conditions may also prohibit spraying. The problem of cleaning the spray equipment between applications often slows the spraying operation and limits the number of treatments.

Our objective was to develop a sprayer that would reduce treatment variations, and that could be used to spray herbicides in a laboratory without danger of contamination.

DESIGN REQUIREMENTS

A study of the requirements for a satisfactory laboratory sprayer showed that we had to consider the following design factors:

Confinement of Spray in an Enclosure

The spray had to be confined in an enclosure that could be housed in the laboratory-greenhouse area. Excess spray had to be collected and removed. Transparent walls or sufficient window area were needed for close observation of the spraying operation. The enclosure had to be large enough to accommodate woody plants up to 4 feet tall, with maximum foliage widths of nearly 4 feet.

Removal of Herbicidal Vapors

Vapor drift is a source of contamination. Because the sprayer would be in a laboratory, near greenhouse facilities and field plots of crops susceptible to herbicides, control of vapor drift was important. Removal of vapors from the air inside the enclosure, and entrapment of the toxic materials in a filter system were required.

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Control of Application Rate

The application rate range would have to be 1 to 30 g.p.a. to simulate most aerial and ground applications of herbicides. Provision for multiple applications was desired, and precise control of applications was required for uniform rates.

Adjustments for Various Sizes of Plants

Because potted plants vary in height from small seedlings to 3 or 4 feet, the distance between the spray nozzle and the plant supporting tray had to be adjustable. This adjustment had to be convenient and had to keep the spray nozzle and plants at accessible heights.

Changing Spray Materials and Cleaning System

Applying several different herbicide formulations and concentrations within a short time requires premixing of the materials. Spraying materials directly from the containers in which they are premixed would eliminate time spent cleaning and refilling a spray container between applications. Thorough and rapid flushing of the sprayer system between treatments, and removing all liquid from the system after flushing were also necessary.

Sprayer Operation and Controls

The sprayer had to be simple and convenient to operate because several different scientists and technicians would be using it. Ample access was needed for easy placement of plants for spraying. Controls had to allow for rapid adjustment in nozzle speed, nozzle pressure, spraying height, etc., and had to be located so that the operator could observe the spraying operation carefully while he controlled it. The nozzle carriage and spray valve had to have provisions for both manual and semiautomatic operation.

GENERAL DESIGN OF SPRAYER

Spray Booth

We built an enclosed spray booth 4 feet wide, 9 feet high, and 16 feet long (fig. 1). The main frame is mostly of 2- by 2-inch ornamental steel tubing. The end sections of a galvanized steel drain pan slope toward the center of the spray booth. The center section (4 by 6 feet) of the drain pan is recessed so that a plant-supporting tray can be lowered to within 6 inches of the floor. This tray is a steel tubing frame covered with expanded metal and is supported at its four corners by 1/8-inch steel cables. Vertical guides at the back corners of the tray prevent horizontal tray movement (fig. 2). A pulley and windlass system (fig. 3) raises and lowers the tray from 2 to 6 feet below the spray nozzle.

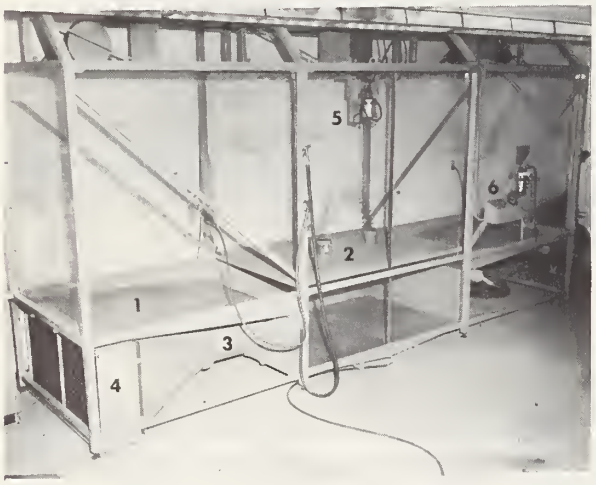


Figure 1.--Herbicide sprayer showing (1) drain pans, (2) adjustable-height plant-supporting tray, (3) exhaust fan, (4) activated charcoal and oil-impregnated filter package, (5) variable-speed spray cart on overhead track, and (6) control panel.

The sides of the booth were covered with clear acrylic sheets 3/16 inch thick to a height of 7 1/2 feet. Two sliding doors 5 feet high and 3 feet wide on the front of the booth provide access to the plant-supporting tray when it is at normal working height. Two hinged doors 3 feet high and 2 feet wide below the sliding doors can be opened to place large plants in the booth (fig. 4).

The steel framework and the drain pans were painted with chemically resistant epoxy resin paint to prevent corrosion.

Spray Cart and Drive System

A cart carries the spray nozzle and herbicide container along the spray booth (fig. 5). This carriage system is similar to those described by other investigators.[2,3] The

[2] Hare, W. W., and Harrell, E. A. An experimental laboratory sprayer for simulating field conditions. U.S. Dept. Agr., Agr. Res. Serv. ARS 42-100, 7 pp. 1964.

[3] Mason E. B., and Adamson, R. M. A sprayer for applying herbicides to pots or flats. Weeds 10: 330-332. 1962.

Figure 2.–Rear corner of plant-supporting tray and vertical tray guide.

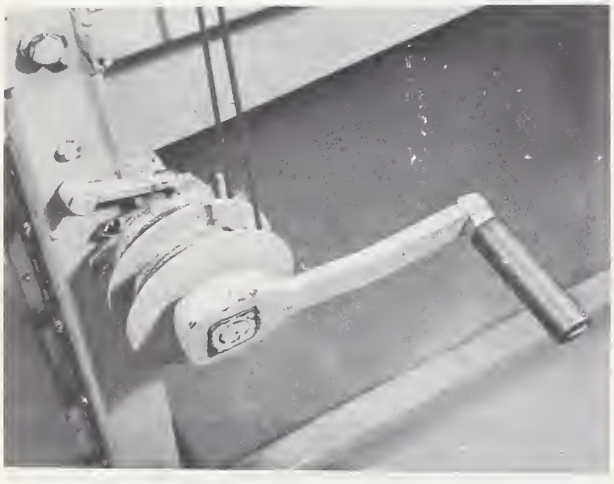


Figure 3.–Windlass for raising and lowering plant-supporting tray.

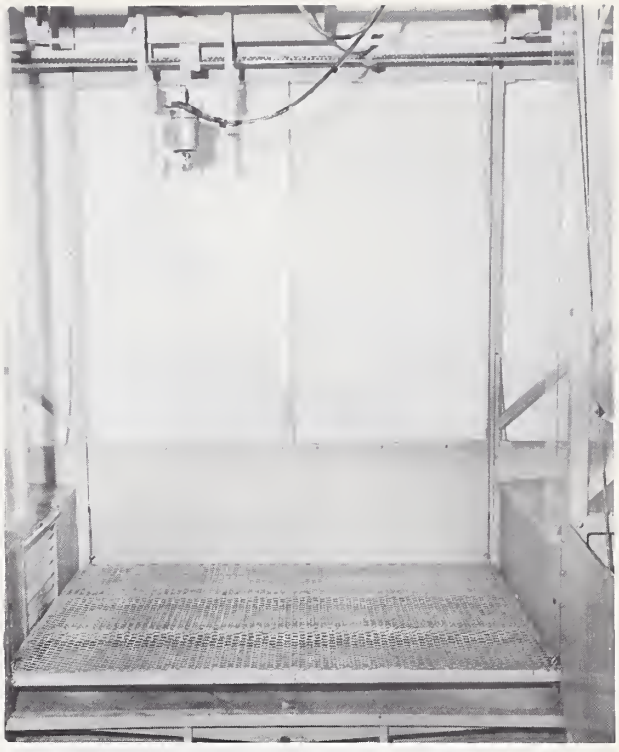


Figure 4.–Front view of sprayer showing tray lowered and doors open to receive large potted plants.

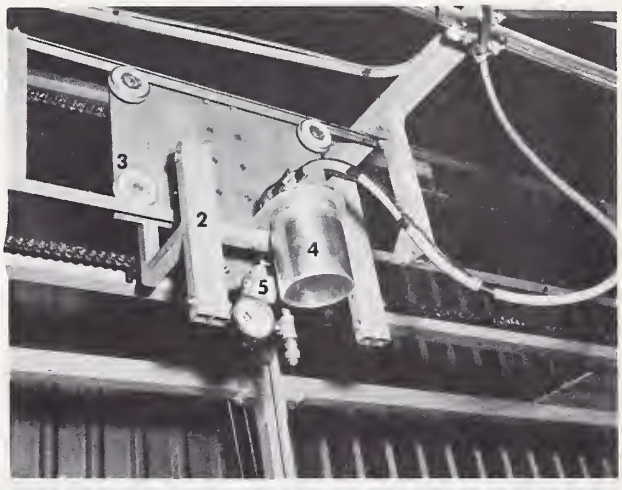


Figure 5.–Spray cart assembly mounted on overhead track. Principal components are (1) secondary track to carry air hose to spray container and electrical leads to solenoid valve on spray cart, (2) cart frame, (3) nylon rollers to carry cart, (4) pressurized spray container, and (5) solenoid valve above gage and nozzle for spray release.

cart frame is made of an aluminum plate 5/16 inch thick and lightweight steel tubing. The cart rests on four nylon rollers 3 inches in diameter and is propelled along an overhead track by a No. 50 steel roller chain carried on two 60-tooth sprockets located at either end of the track. A roller bearing 1 1/2 inches in diameter is fastened to an attachment link in the chain and operates in a vertical slot on the back of the spray cart plate to provide a mechanical linkage between the drive chain

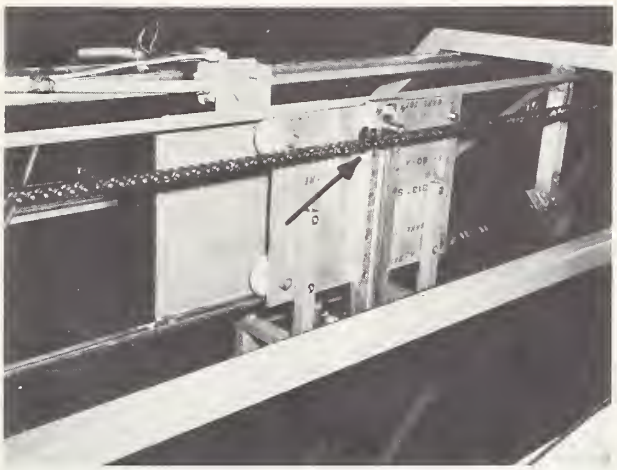


Figure 6.--Back side of spray cart showing roller bearing operating in vertical slot and attachment of bearing to drive chain.

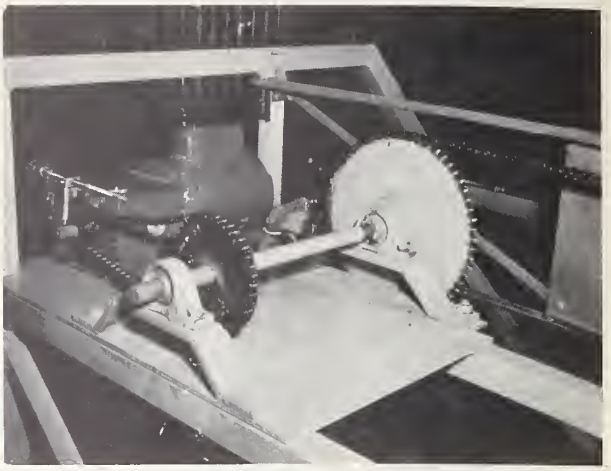


Figure 8.–Variable-speed drive unit with screw-type speed control.

and the cart (fig. 6). This mechanism operates as a crank driving a yoke or cam to reverse the cart as the roller bearing is carried around the sprockets (fig. 7). The roller chain propelling the cart is driven by a 1/2-hp. Zero-Max variable-speed drive unit through a counter-shaft arrangement (fig. 8). Cart speed is continuously variable from 0 to 5 m.p.h. Although faster cart speeds are possible by changing drive sprocket ratios, their value is questionable because of the sloshing of the spray solution in its container and the greater strain on the drive system during the reversing process.

Sprayer Unit

The spray system consists of a 1-quart pressurized paint spray can, a solenoid operated valve, a pressure gage, and a nozzle (fig. 5). A flexible rubber hose supplies air pressure. One end of the hose is attached to the top of the pressure can and the other end to an air line at the top of the spray booth frame. The center of the hose is supported by a nylon wheel traveler that is pulled back and forth on an 8-foot overhead track.

A 200 ml. glass bottle containing the herbicide solution is placed inside the pressurized spray can (fig. 9). A cylindrical metal sleeve centered in the can by

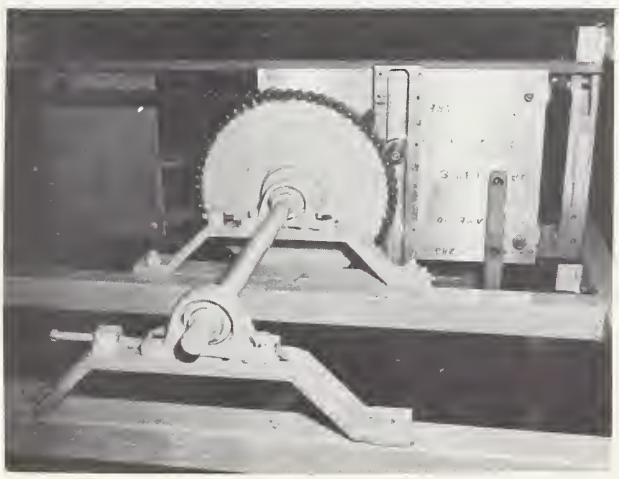


Figure 7.--Back side of spray cart showing the roller bearing attached to the drive chain moving downward in the vertical slot. This mechanism stops the cart and reverses its direction as the bearing is carried around the sprocket.

Figure 9.--View of (1) pressure can, (2) 200-ml. glass bottle, and (3) bottle cap with short length of copper tubing soldered to underside to serve as a splashguard. (Two 1/16-inch holes in the tubing just below the cap allow air to enter the bottle without disburbing the spray solution.)

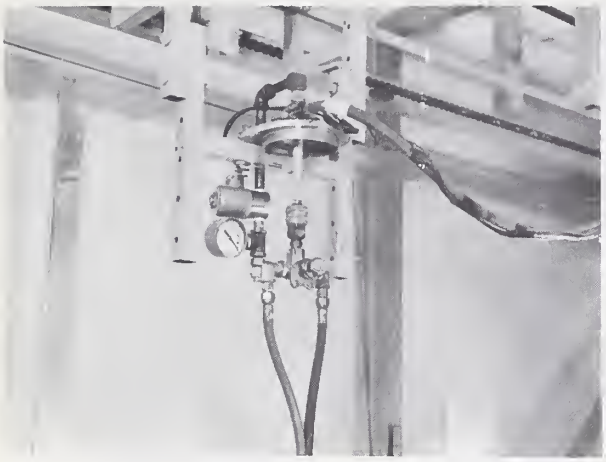


Figure 10.–Water and air lines connected to liquid uptake pipe for flushing and drying spray system.

Figure 11.–Air filtration system showing (1) exhaust fan housing and (2) caster mounted filter package buckled to transition duct.

compression springs holds the bottle. The liquid uptake pipe extends through a hole in the bottle cap to a point near the bottom of the herbicide bottle, permitting nearly all of the material in the bottle to be sprayed. A short length of copper tubing soldered to the underside of the cap serves as a splashguard to prevent spillage when the spray cart reverses. The spray pipe, valve, and nozzle can be flushed with water and dried with air by attaching water and air lines to the end of the liquid uptake pipe after the pressurized can is removed (fig. 10). The male portion of a quick-attach coupling was welded to the end of the liquid uptake pipe, and water and air hoses were attached to the female portion of a coupling through a three-way valve. If flushing the spray system with water is not sufficient, solvent or some neutralizing solution can be used.

Air Filtration System

A 1,400-c.f.m. axial duct exhaust fan 16 inches in diameter was installed to draw air out of the booth through a louvered opening in a vertical side of the drain pan, and to force it through two 24- by 24-inch activated charcoal filters mounted side by side. Air from the room is drawn into the top of the booth. To make the charcoal filters last longer, oil-impregnated dust filters were placed ahead of them. The charcoal filters used are Dorex Type 42C cells. The filter frames were fastened together and mounted on rollers under the end of the drain pan, as shown in figure 11. A horizontal frame member can be removed to permit the filter package to be rolled from under the drain pan. A detachable, carbon-filled test element is clipped to the front of the activated charcoal filters. Periodically the test element is removed and returned to the manufacturer for quantitative absorption analysis to determine the degree of saturation. The filters are replaced when they become saturated.

The fan on the air filtration system operates as soon as spray droplets are deposited after each spraying operation. The automatic-reset interval timer that controls the fan allows adequate time to replace the air in the booth with clean air.

Control System

The control panel on the front of the spray booth provides either manual or semiautomatic control of the spray cart and solenoid-operated spray valve (fig. 12).

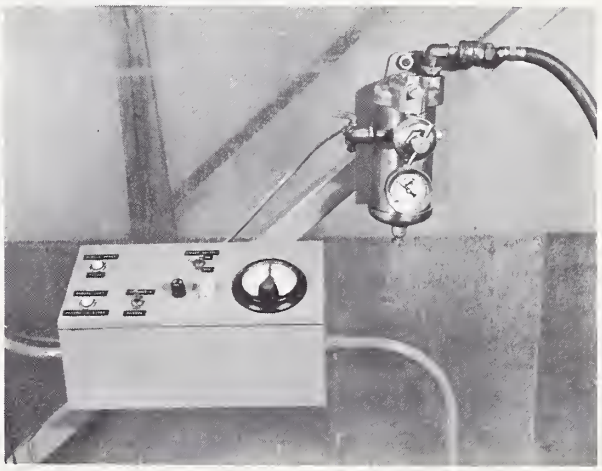


Figure 12.–Control panel, air pressure regulator, and gage and moisture extractor.

Trip blocks attached to the drive chain (fig. 13) actuate a snap-action switch to provide semiautomatic operation of the spray cart and spray valve. Repositioning the trip blocks on the drive chain varies the spraying distance for semiautomatic control. A regulator on a moisture extractor located near the control panel (fig. 12) adjusts air pressure for spraying. An air valve for pressurizing the spray can also bleeds pressure from the can when in the off position.

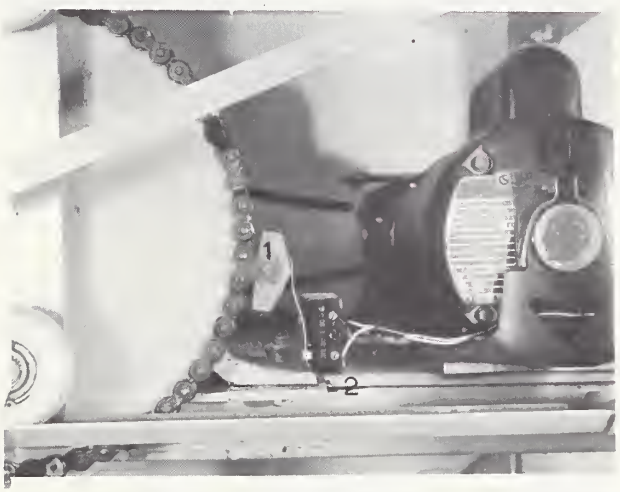


Figure 13.–View showing (1) trip block attached to drive chain and (2) snap-action switch that provides semiautomatic control of the spray cart and spray valve.

Figure 14.–Handwheel, revolution counter, and roller chain used to adjust screw-type control on variable-speed drive unit.

Spray cart speed is adjusted by a handwheel on the front of the spray booth. A sprocket on the handwheel shaft (fig. 14) drives a No. 35 steel roller chain that in turn operates a screw-type control on the variable-speed drive unit. A mechanical counter is attached to the handwheel shaft. A calibration table is provided to read in miles per hour and feet per second, speeds corresponding to the counter settings.

Figure 15 shows the electrical circuit diagram for the control panel.

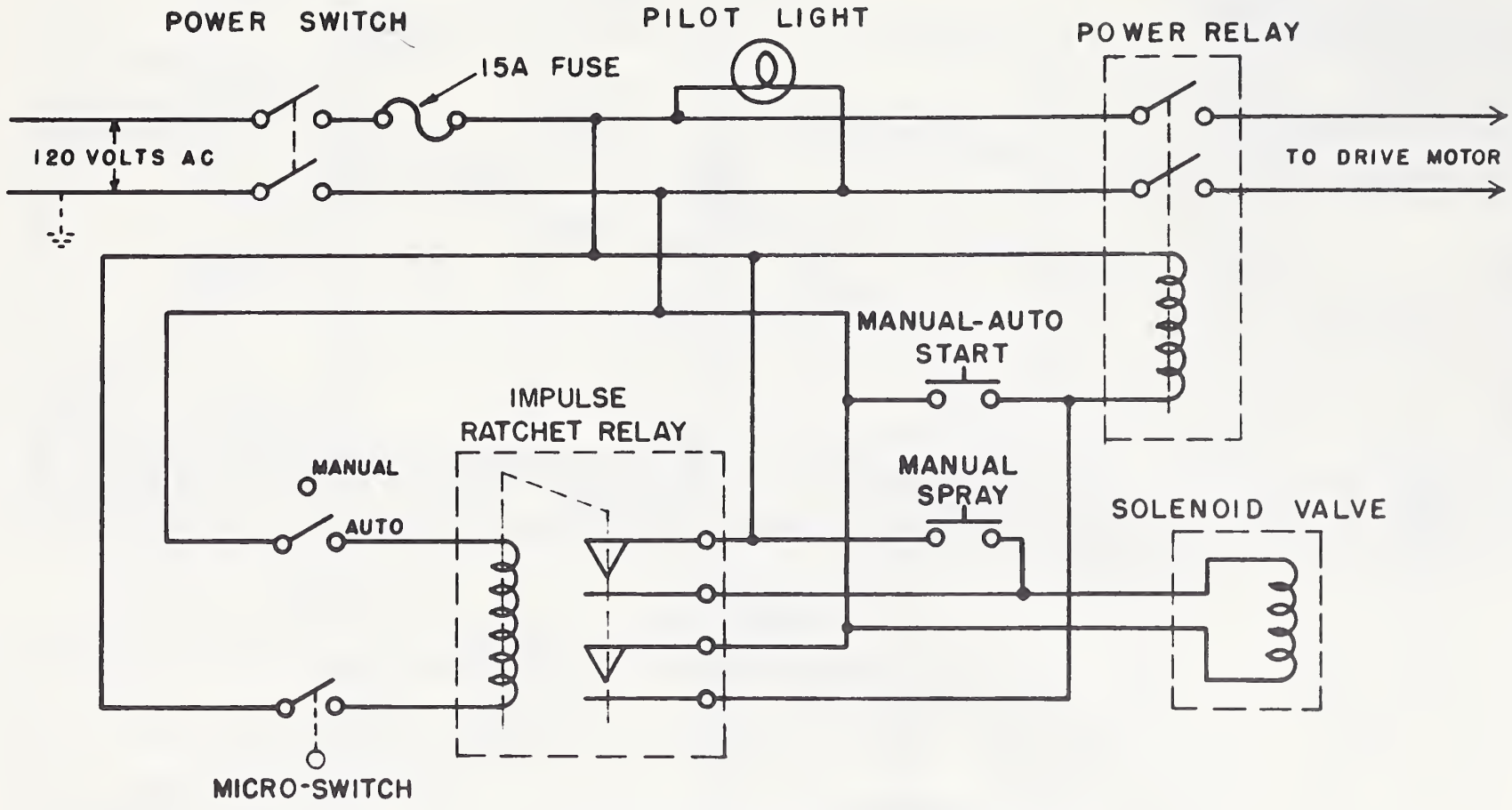


Figure 15.–Laboratory sprayer wiring diagram.

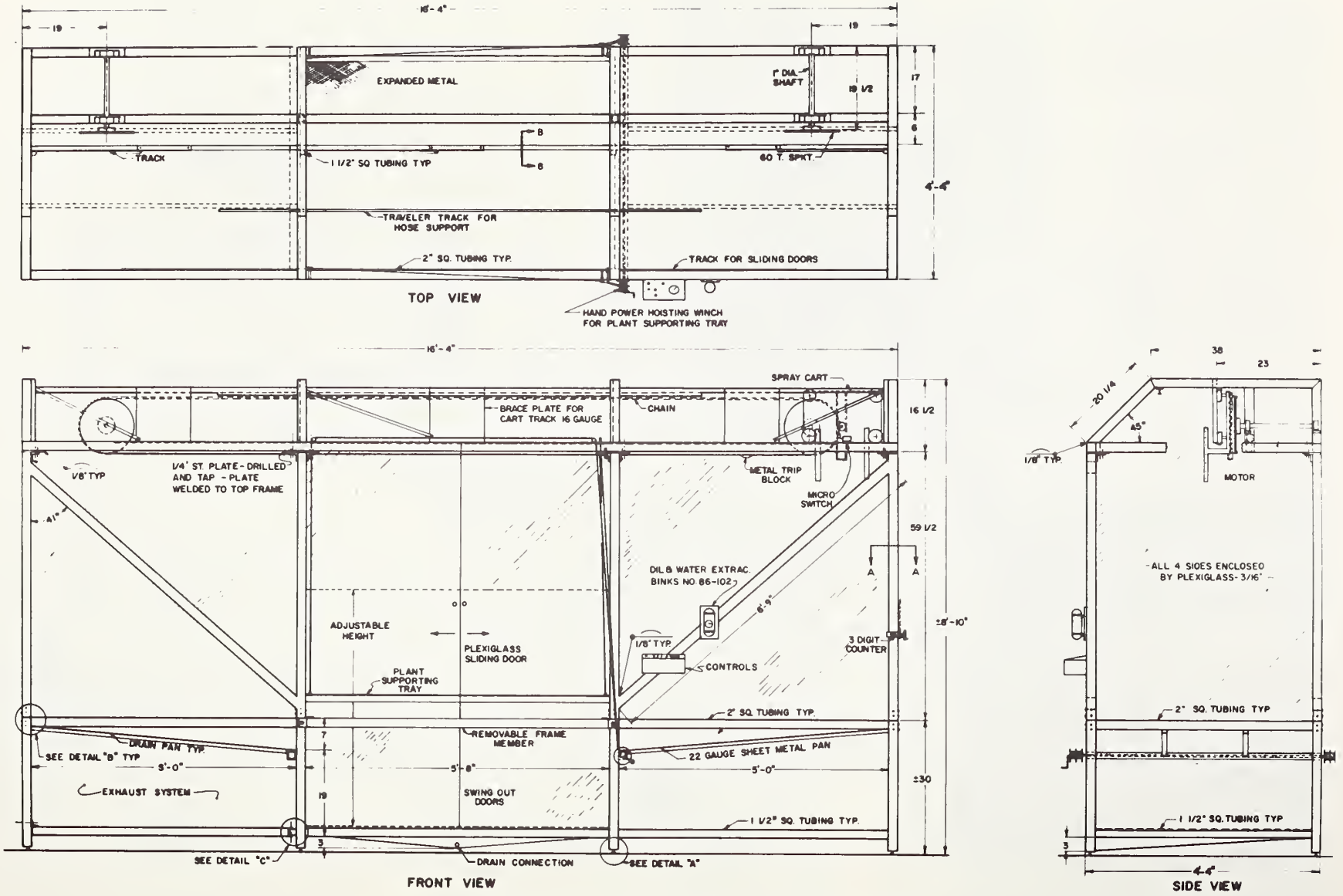
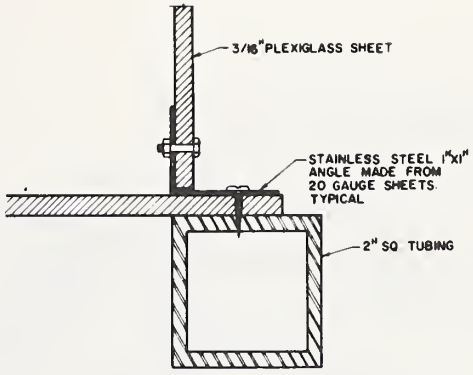
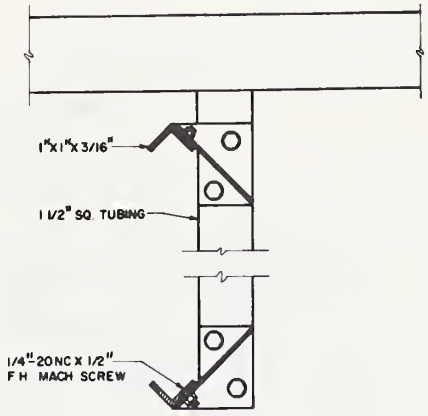


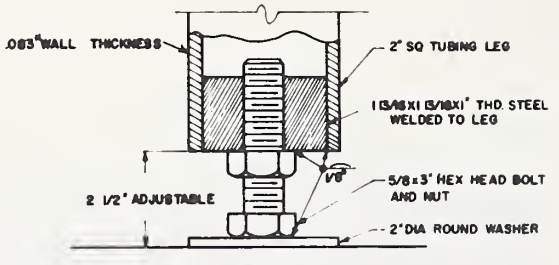
Figure 16.–General layout of sprayer framework and components.



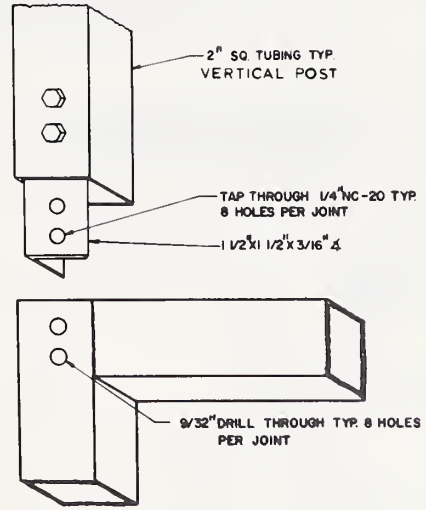
SECTION A-A
TYPICAL FOR 4 CORNERS



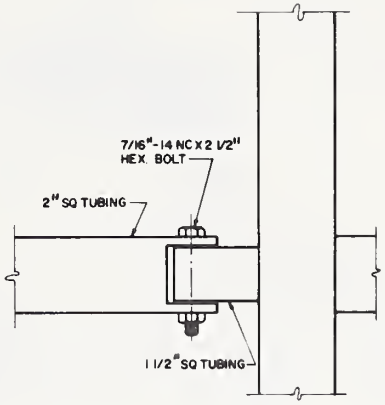
SECTION B-B
SPRAY CART TRACK



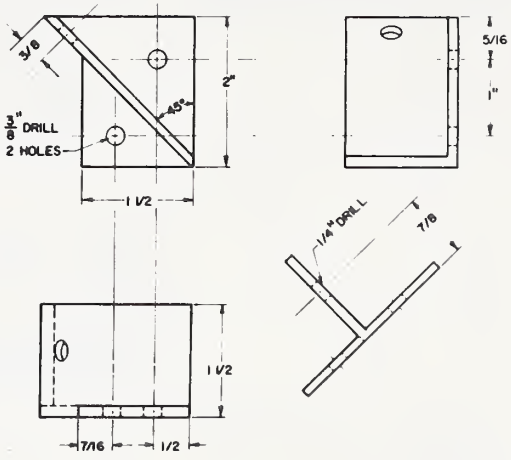
DETAIL "A"
LEG LEVELER



DETAIL "B"
POST ASSEMBLY JOINT

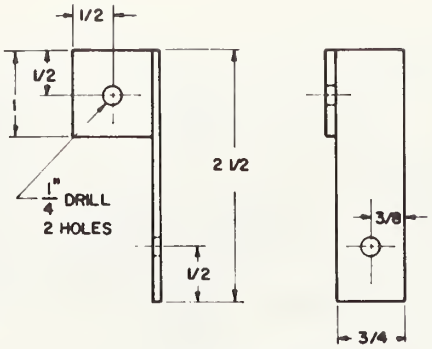


DETAIL "C"
HINGED FRAME MEMBER
FOR FILTER ACCESS

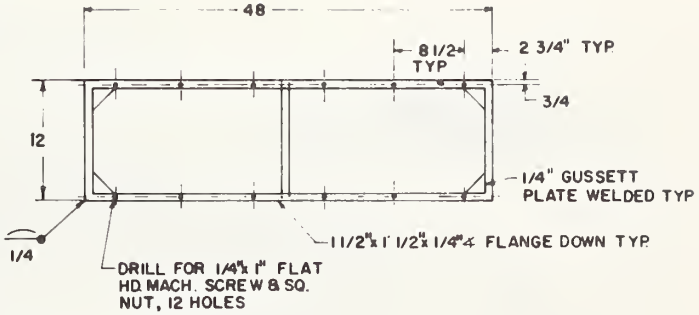


LEFT HANDED TRACK SUPPORT BRACKET
4 LEFT HANDED BRACKET REQ'D
4 RIGHT HANDED BRACKET REQ'D

Figure 17.–Framework construction details.



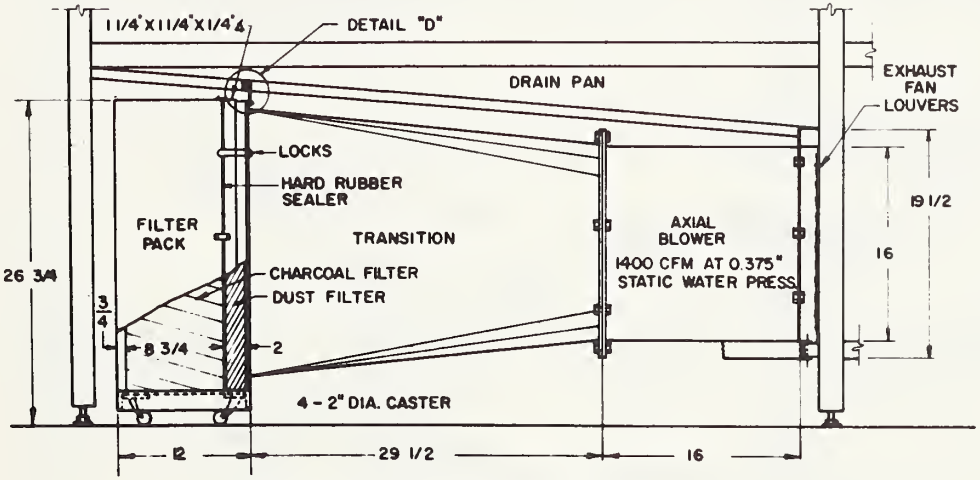
DETAIL "D"
SUPPORT BRKT.
2 REQ'D



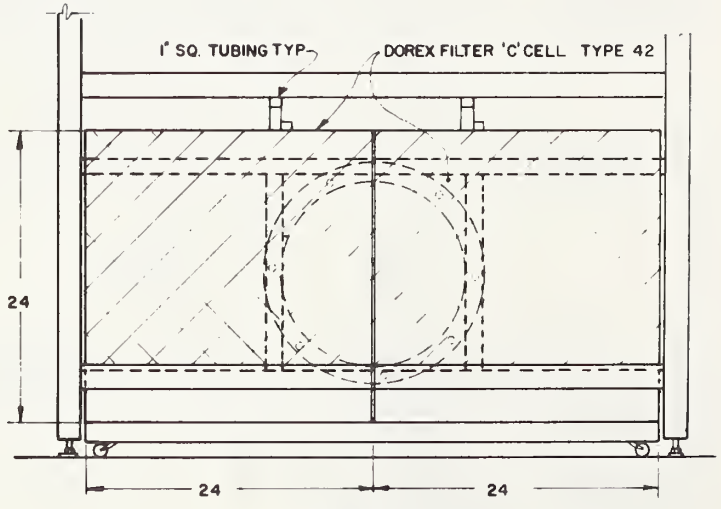
BASE FRAME

NOTE. FILTER PACK CAN BE OPENED BY REMOVING LOCKS AND ROLLING IT OUT. PACK MUST BE REMOVED TO INSPECT OR CHANGE FILTER.

NOTE: 8 LOUVERS 2 1/4" WIDE NORMALLY CLOSED EXCEPT DURING FAN OPERATION.



FRONT VIEW OF EXHAUST SYSTEM



END VIEW

Figure 18.--Air filtration system layout and details.

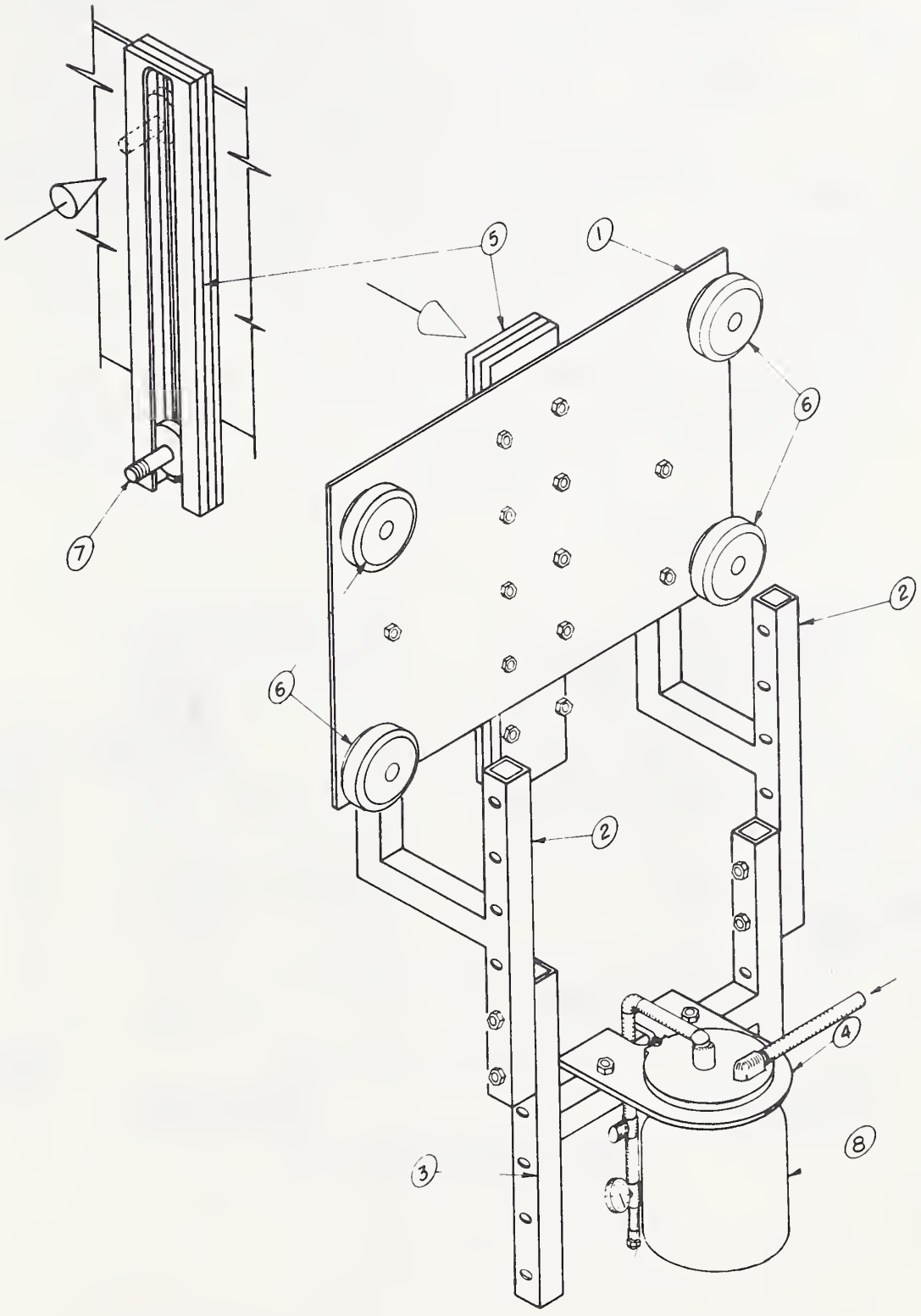


Figure 19.–Isometric drawing of spray cart.

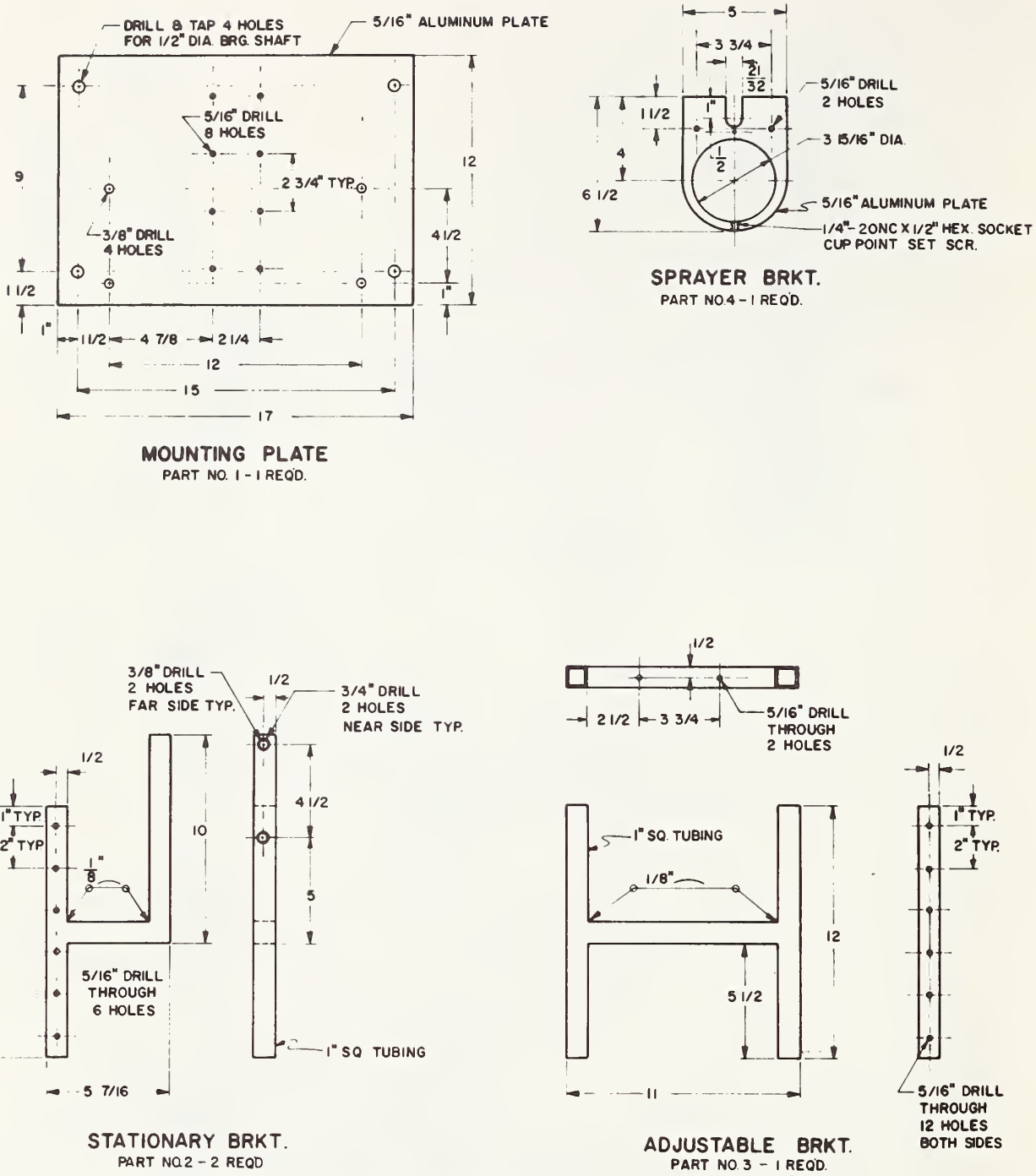


Figure 20.–Details of spray cart components.

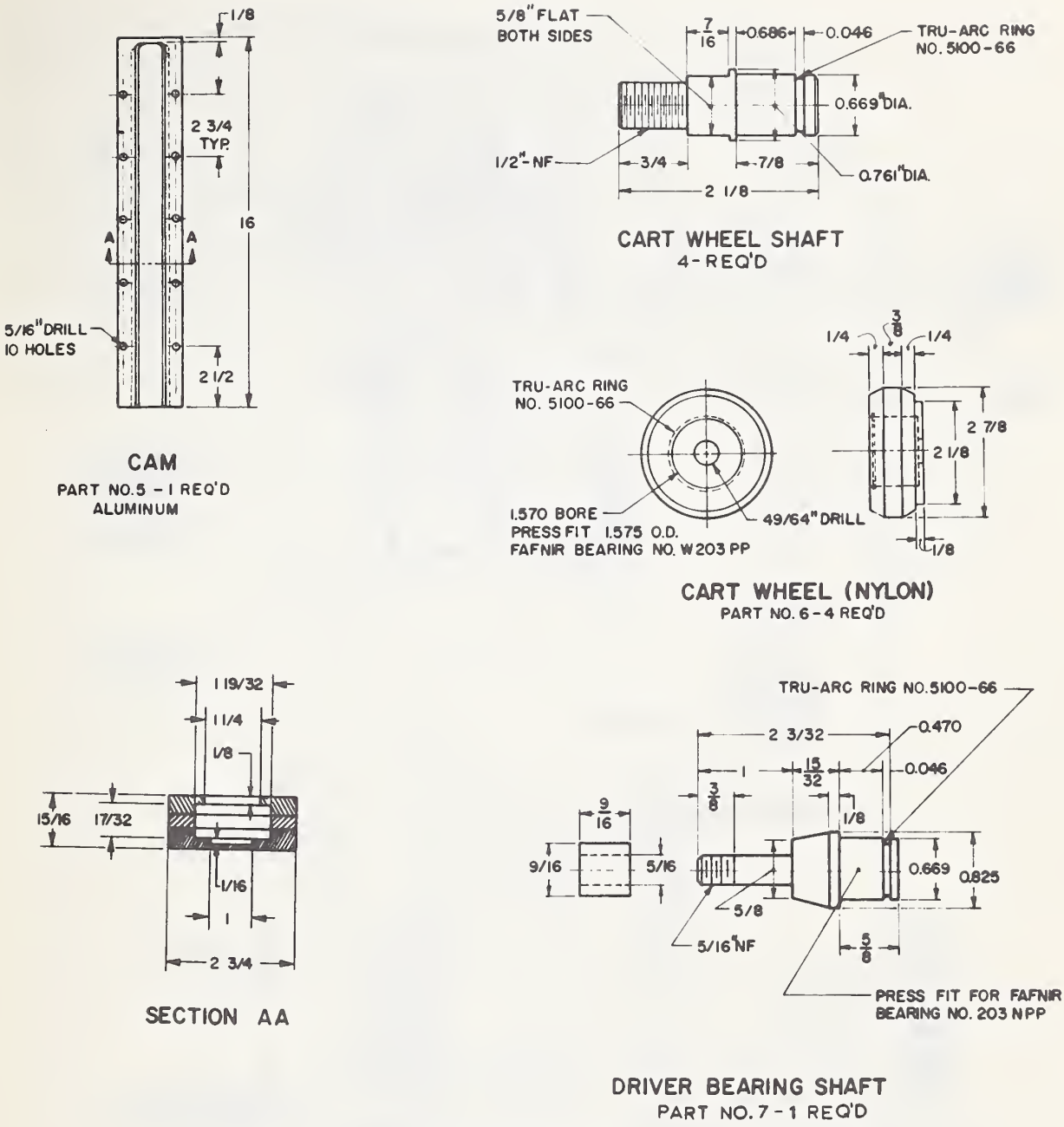
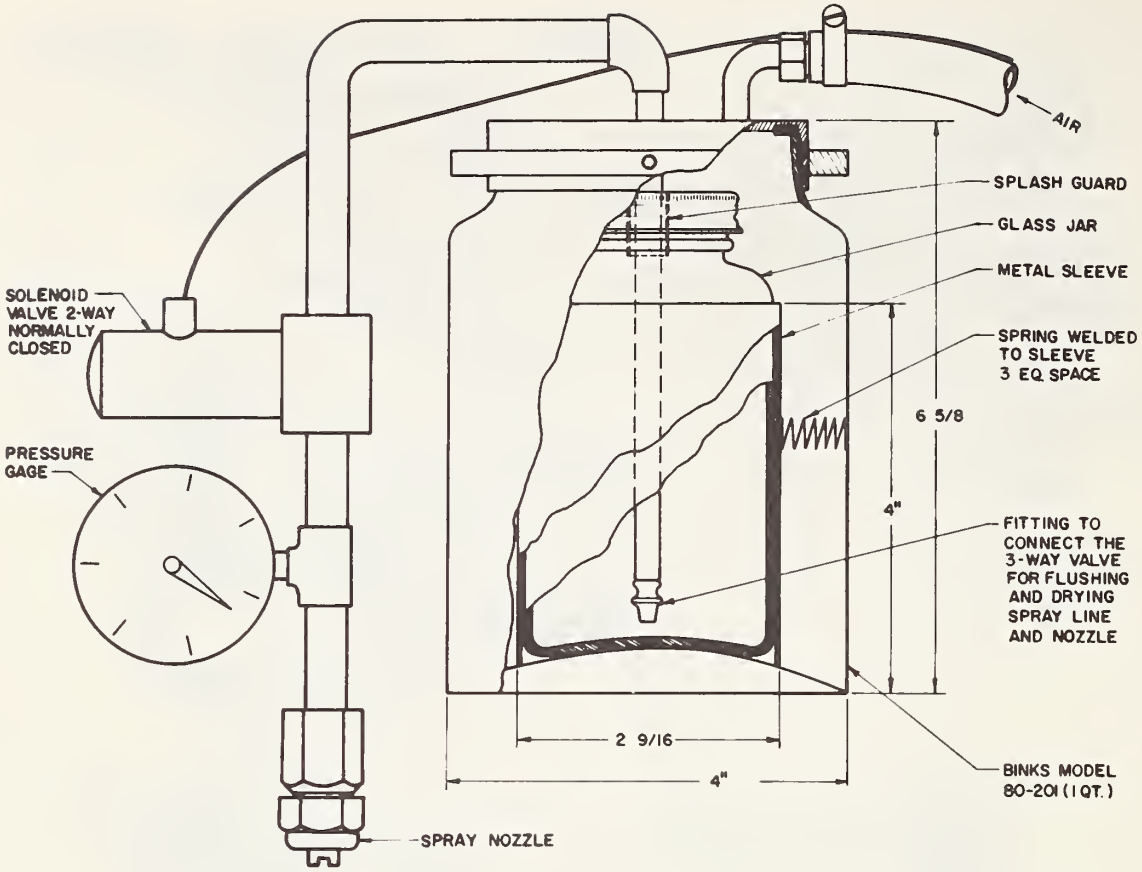


Figure 21.–Details of spray cart components.



PRESSURIZED SPRAY CAN
PART NO. 8

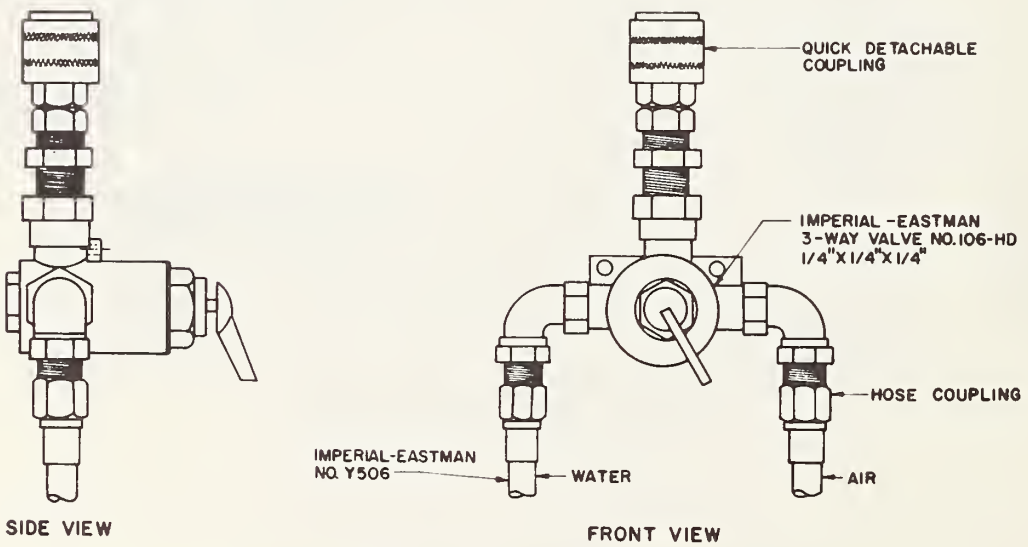
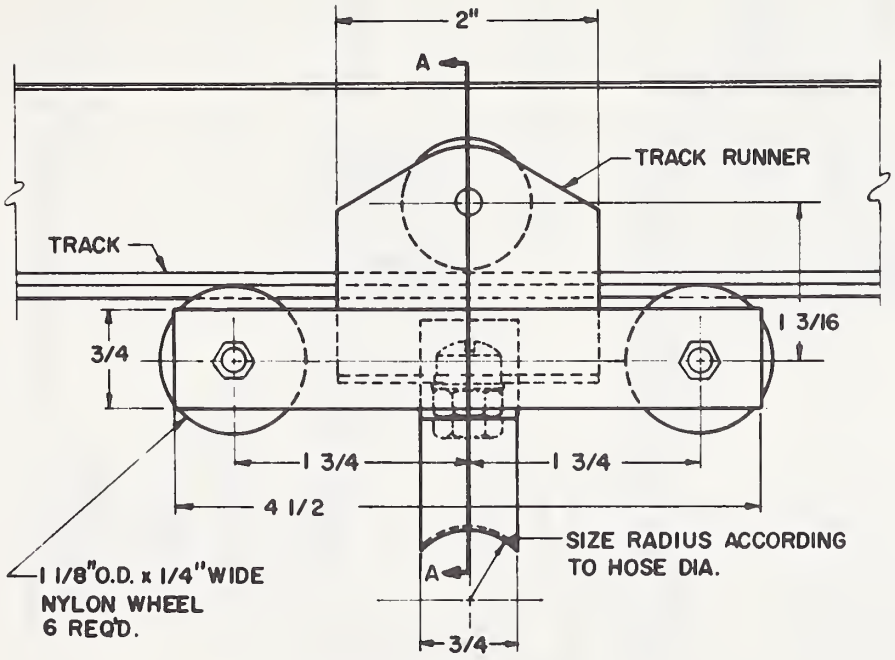
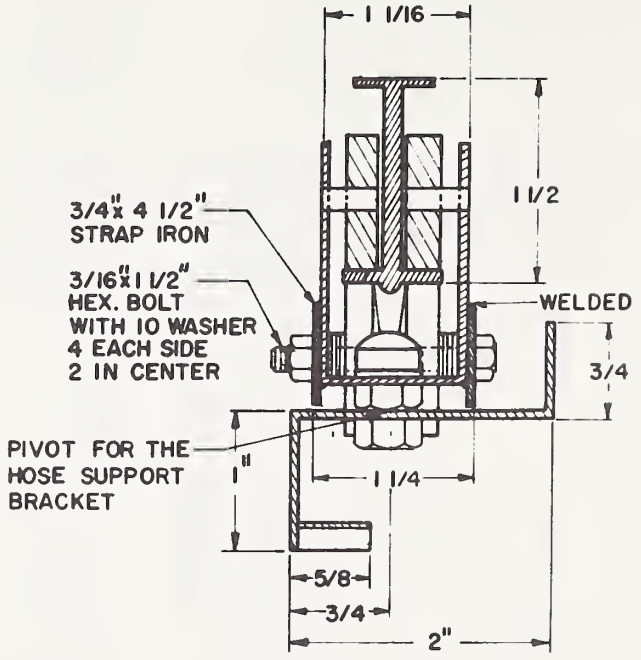


Figure 22.–Details of spray system and flushing- and drying-assembly plumbing.

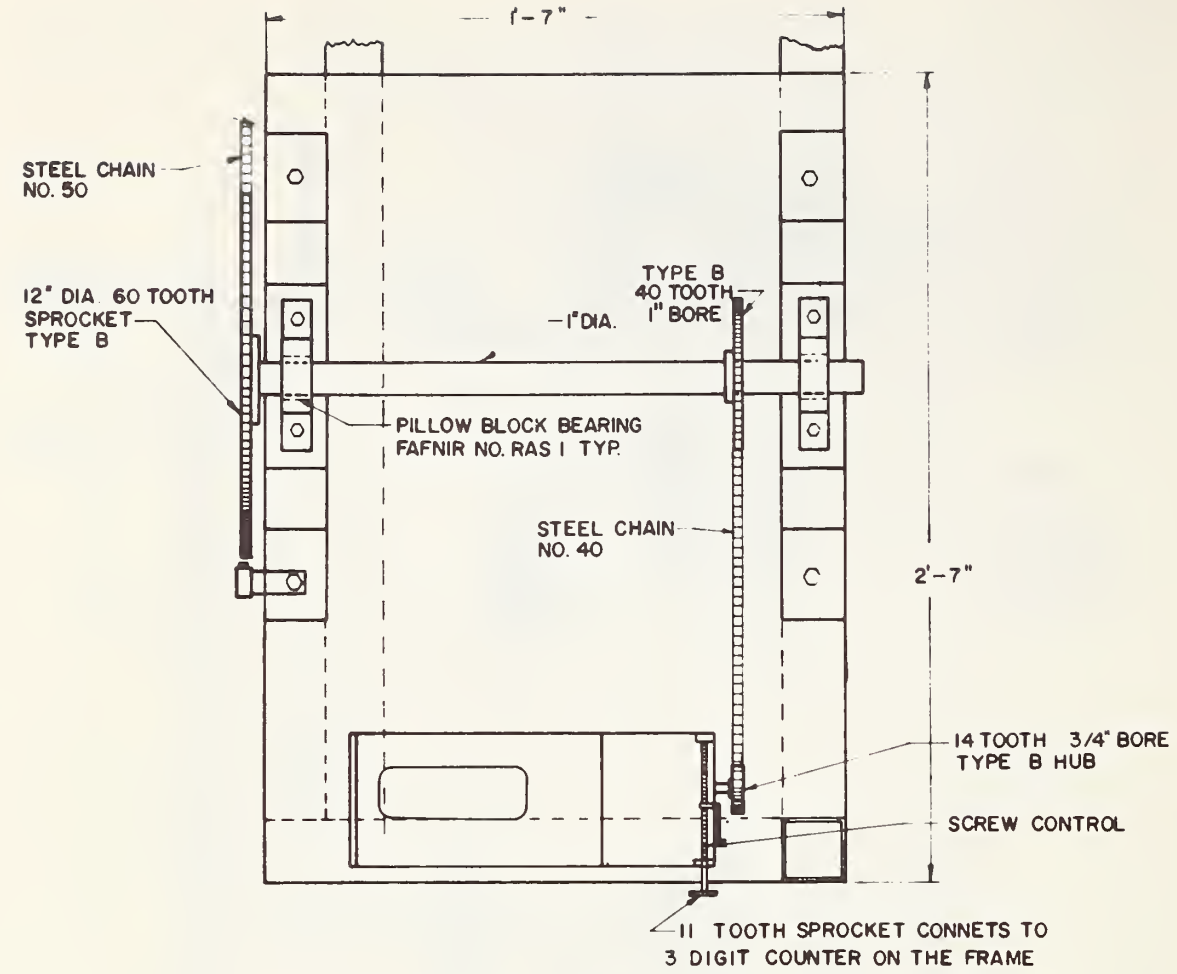


TRAVELER DETAIL
FOR HOSE SUPPORT

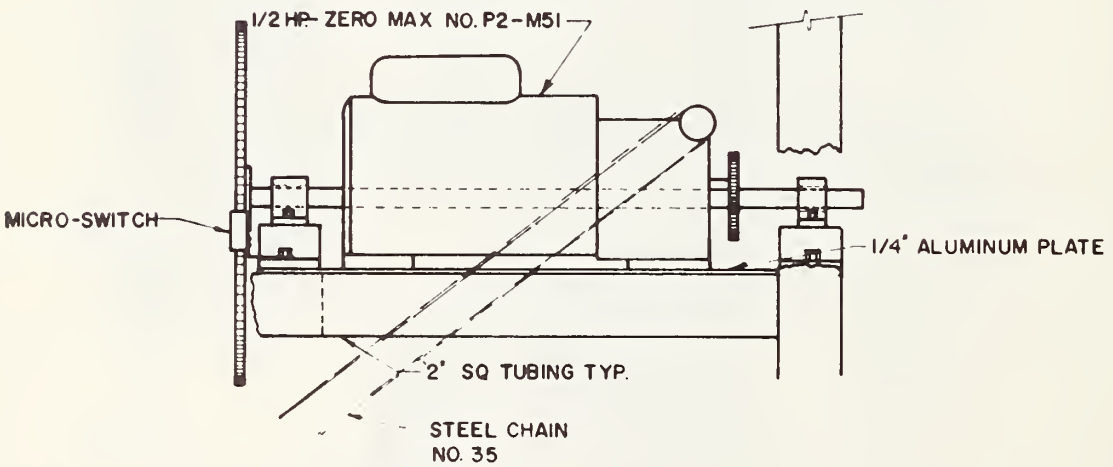


SECTION A-A

Figure 23.–Construction details for modified closet door carriage used to transport air hose and electrical wire to solenoid valve.



TOP VIEW OF VARIABLE SPEED CONTROL
DRIVE UNIT AND GEAR ARRANGEMENT



SIDE VIEW

Figure 24.–Arrangement of variable-speed drive unit and countershaft system.

SPRAYER PERFORMANCE

At the time this report was written, the sprayer had been operating satisfactorily for about 3 years with a minimum of maintenance and repair. Many investigators have used the sprayer to apply a wide variety of herbicides to plants grown in greenhouses and growth chambers, and to soil in petri dishes. The unit has also been used to study a new principle for applying systemic insecticides to plant stems by adding special attachments to the spray cart. The sprayer has often been used to make up to 50 separate precision herbicide applications in a day, using premixed spray solutions. Five to ten plants were sprayed during each application.

The air filtration system required servicing after about 2 years of fairly heavy use. The oil-impregnated dust filters were washed and reoiled and the activated charcoal filters were replaced. The quick-attach couplings and the liquid inlet tube in the pressurized spray can have had some minor corrosion problems. We recommend using brass, stainless steel, or other corrosion-resistant materials.

CONSTRUCTION DETAILS

Figures 16 through 24 show construction dimensions and details for those who wish to build a similar sprayer. A list of materials is also included. Estimated cost of materials to build the sprayer was $1,850 in 1965.

LIST OF MATERIALS

Metal for Main Framework and Drain Pan

Ornamental steel tubing, 2 in. square, 180 ft.
Ornamental steel tubing, 1 1/2 in. square, 100 ft.
Ornamental steel tubing, 1 in. square, 40 ft.
Steel angle, 3/4 in. by 3/4 in. by 1/8 in., 2 pieces 16 ft. each (track for spray cart)
Galvanized sheet metal, 22-gage, 48 in. wide, 100 square ft. (for drain pan)
Aluminum plate, 17 in. by 28 in. by 5/16 in. (1 piece for drive unit platform)

Materials for Adjustable Height Plant Supporting Tray

Ornamental steel tubing, 1 1/2 in. square, 32 ft. (frame)
Steel angle, 1 in. by 1 in. by 1/8 in., 20 ft. (stabilizer and guide)
Expanded metal, 3 ft. 10 in. by 5 ft. 10 in., one piece
Steel cable, 1/8 in., 75 ft. (to raise and lower tray)
6 pulleys, 1 1/2 in. in diameter (for cable)

Materials for Spray Cart

Aluminum plate, 17 in. by 12 in. by 5/16 in. thick, (1 piece)
4 nylon rollers, 3 in. outside diameter by 15/16 in. wide, (machined from 3-in. diameter nylon stock)
4 single-row radial-sealed ball bearings 17-mm. bore, 40-mm. outside diameter, 0.6875 in. wide (wide type); (Fafnir No. W203PP, mounted by press fit and retainer ring into nylon rollers)
Ornamental steel tubing, 1 in. square by 10 ft. long

Spray Cart Drive Materials

4 self-aligning pillow block bearings, 1 in. bore (Fafnir No. RAS 1)
2 cold-rolled steel shafts, 1-in. diameter by 22 in. long
2 steel sprockets for No. 50 steel roller chain, 60-tooth, 1-in. bore, type B hub
1 steel sprocket for No. 40 steel roller chain, 40-tooth, 1-in. bore, type B hub
1 steel sprocket for No. 40 steel roller chain, 14-tooth, 3/4-in. bore, type B hub (mounted on Zero-Max drive unit)
Steel roller chain, No. 50, 32 ft.
Steel roller chain, No. 40, 4 ft.
7 type S2 (Dodge), pin link attachment links for No. 50 steel roller chain (to attach microswitch trip blocks and cart drive bearing to cart drive chain)
1 single-row radial-sealed ball bearing, 17-mm. bore, 40-mm. outside diameter, 12 mm. wide (Fafnir No. 203NPP, attached to cart drive chain—outside of bearing rides in vertical slot on back of spray cart)
1 Zero-Max drive unit, 1/2 hp., clockwise rotation, Model P2M51, 0-400 r.p.m.
2 steel sprockets for No. 35 steel roller chain, 11-tooth, 3/8-in. bore, type B hub (for Zero-Max speed adjustment)
Steel Roller Chain, No. 35, 12 ft. (for Zero-Max speed adjustment)
1 revolution counter, 3-digit, reversible, nonreset (attached to Zero-Max control knob for speed calibration)

Air Exhaust and Filter System

1 direct-drive axial-duct fan with aluminum impeller, 16-in. inside diameter, galvanized iron housing and explosion-proof motor for 115-volt, 60-cycle; delivers 1400 c.f.m. at 0.375 in. static water pressure at 1750 r.p.m. (purchased from Airfoil Impellers Corp., P.O. Drawer A, College Station, Tex.)

2 activated charcoal filters, type No. 42C Cells, mounted in 24-in. by 24-in. frames (purchased from Conner Engineering Corporation, Danbury, Conn.)

2 dust filters, oil-impregnated, 24 in. by 24 in. (placed ahead of charcoal filters to make charcoal filters last longer)

Spray System

1 pressurized paint sprayer cup, 1-quart, modified for use. (Cat. No. 80 - 201, Binks Mfg. Co.)

1 oil and water extractor, 20 c.f.m. (Model No. AO-102, Binks Mfg. Co.)

1 solenoid valve, 2-way normally-closed, stainless steel with viton seat, for operation on 115-volt 60-cycle AC.

Materials for Enclosing Sides of Sprayer

Plexiglas–3/16 in. thick by 60 in. wide, colorless transparent, *untrimmed* Plexiglas "G" grade sheets (*untrimmed* 60-in. sheets provide approximately 2 in. additional width that is needed)

- 2 sheets, 8 ft. long (for back)
- 1 sheet, 8 ft. long (cut into two 4-ft. pieces for ends)
- 1 sheet, 10 ft. long (cut into two 5-ft. pieces for front panels)
- 1 sheet, 7 ft. long (cut into two 3 1/2-ft. pieces for sliding doors)
- 2 pieces, 2 ft. by 3 ft. each (for lower front hinged doors)

Brass piano hinge 4 ft. x 3/4 in. (for lower front doors).

Strips of 22-gage stainless steel, 16 ft. by 2 in., formed into 1-in. by 1-in. angle (to hold Plexiglas in corners)

Strips of 22-gage stainless steel, 30 ft. by 2 in. (for splicing Plexiglas panels and forming baffles for doors)

Control System

1 standard-duty, flat-leaf type snap-action switch, 15-amp., 110-volts AC, (actuated by trip blocks on cart drive chain for semiautomatic cart and solenoid valve control)

1 heavy-duty PR-type power relay, 110-volts AC coil, 20-amp. contacts (Zero-Max drive control)

1 impulse ratchet relay, 110-volts AC coil, double pole, double-throw type (for automatic control of Zero-Max relay and solenoid valve)

2 flush-mount pushbutton switches (for manual control of solenoid valve and cart and for initiating automatic control system)

1 automatic reset interval timer, 0-60 seconds, 15-amp. contacts (for exhaust fan control to allow sufficient operating time to change air in spray booth)

1 double-pole single-throw toggle switch (to cut off all power to sprayer) 15-amp.

1 single-pole single-throw toggle switch (to select either manual or automatic cart and solenoid control)

1 indicator light, 115-VAC.

1 fuse holder and fuse, 15-amp.

Miscellaneous

Track with free-rolling carriage to support air hose and wiring to spray cart, (1 piece, 8 ft. long). (Closet door track and rollers were used with some modification.)

Air hose, 10 ft. (to supply air from top of sprayer to pressurized spray container)

Plumbing as desired for washing and draining booth.

Air and water supplies for flushing and drying spray system (twin gas welder hose and 3-way valve with quick-attach coupling to spray liquid inlet tube permitted flushing with water first and then drying with air).

Miscellaneous bolts, nuts, washers, pipe fittings, screws, and electrical and other hardware items as needed for construction